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RESEARCH ARTICLE

Congestion Management and Demand Side Response in Wholesale Power Market

Prakash Kerur[1], R.L. Chakrasali[2]
[1]Department of Electrical and Electronics Engineering, KLE Institute of Technology,
Hubballi, 580 027, Karnataka, India
[2]Department of Electrical and Electronic Engineering, SDM College of Engineering & Technology,
Dhavalagiri, Dharwad, Karnataka 580002, India

ABSTRACT: Congestion management is a common issue in power system and becomes more challenging task in competitive electricity market. Power lines are often loaded beyond their thermal limits in order to satisfy the increased demand. With increase in demand the unplanned power exchange takes place between producers and consumers. In the deregulated electricity market, Independent System Operator (ISO) is the one responsible for keeping track of various transactions taking place between various entities. The ISO is an entity entrusted with the responsible of ensuring the reliability and security of the entire system. Therefore Congestion Management and Demand Side Response are very necessary in this context. The economical benefit comes from reducing the line losses. This is because the energy usually has to travel a considerable distance from power plants to customers. These two concepts contribute in relieving heavily loaded lines and reducing losses. Demand Side Management (DSM) provides an excellent reliability resource for the most critical reliability needs. The graph theory shortest path algorithm finds more suitable to identifying the shortest path power flow and determination of Available Transfer Capacity (ATC) in the lines avoids unnecessary loading the lines to avoid the congestion in the power network.

KEYWORDS: Congestion management, Demand Side Management, Deregulated electricity market, Dijkstra's algorithm

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1. INTRODUCTION

In the power system if the power flows were not controlled, some lines located on particular paths may become overloaded and this phenomenon is called congestion Demand response can solve the congestion problems in an efficient way. Rather than directly shedding load, congestion management through Demand side Response (DR) focuses on rescheduling or postponing load demand /diverting the power through alternative path / determining the ATC of the lines to determine the power flow capacity to reduce the congested power flow. In deregulated power system transmission networks plays vital role in competitive electricity markets, because in some cases lines are open for maintenance and repair, the load is shifted to other line, which is already loaded. To facilitate the coordination of action needed from load resources, a local market could be introduced. Each power producers and consumer should participate in this market can submit a bid of curve, indicating their cost of providing congestion management service. All the bids are evaluated relatively to their effectiveness in alleviating congestion. Ancillary services are necessary to support the transmission of energy to loads while maintaining reliable operation of the power system. These operating reserves serve as additional capacity to keep a balance between load and generation. [4-6]

This trend is slowly shifting in modern power systems. The movement being observed is toward ensuring energy security and reducing industry's carbon footprint by integrating renewable and distributed energy resources, and through the implementation of energy efficiency programs. The rapid increase of renewable energy resources, with energy security and environmental betterment objectives, poses significant challenges to the secure operation and planning of power systems. This is particularly due to the need for higher levels of flexibility and controllability to accommodate the intermittency in energy produced by renewable energy

**Corresponding Author: prakashkerur@gmail.com*
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resources. In this environment, the demand side is expected to play an increasingly active role in maintaining the supply demand balance by providing the required flexibility to follow. This is in distinct contrast with the traditional power systems operation and planning paradigm in which generators are controlled to follow the demand as it varies over hours, days, seasons and years. [4, 5]

Benefits of demand-side management

DSM can bring a variety of benefits to the power industry, ranging from economical to environmental benefits are as follows.

1. Economic benefit comes from reducing the peak demands. Although peak demands are infrequent in power systems, their economic impacts are significant. This is mainly because energy prices skyrocket during peak demand and supply shortages.

2. Economic benefit comes from providing ancillary services, and potentially decreasing the volatility of the demand. Generally, ancillary services are provided by generating units running in a sub efficient mode of operation. Such costly situations could be substituted in part by employing demand response (DR) capacity. The provision of ancillary services by DR can further reduce the need for running costly power plants, such as quick start and peaking units driving production costs.

3. Economic benefit comes from reducing the transmission and distribution losses. This is because the energy usually has to travel a considerable distance from producers to customers. The transmission losses vary between 5 and 10% depending on the loading conditions of transmission and distribution lines. DSM can contribute in relieving heavily loaded lines and reducing losses .DSM provides an excellent reliability resource for the most critical reliability needs.
4. Environmental benefits it reduces the power generation by fossil fuels and reduces carbon footprints [1, 2].

Graph Theory is employed in many fields of engineering especially in transmission loss allocation problem and identifying shortest path for power flow in the complex network. Graph theory based algorithms' provides satisfactory results. The benefits of graph theory algorithms, is that the results provided are in the form of graphical representations which helps the power engineers to plan the work according to graph [7,8].

Problem Statement

In the deregulated electricity market many power individual power producers will compete in the power trading Competitive markets provide the driving force for generators to innovate and operate in the most efficient and economic manner in order to remain in the business and recover their costs. In the power system if the power flows were not controlled, some lines located on particular paths may become overloaded and this phenomenon is called congestion. In deregulated scenario many sources of power generation, several route of power flow this make power network more composite The objective of this work is to avoid this congestion management and DSM is introduced in the wholesale power market and find the optimal path in the power system network to enhance the power system reliability and security. Using Dijkstra's algorithm it is possible to reduce the line losses to some extent by providing the shortest path and determination of ATC in the lines avoids congestion in the network and makes Demand side management. [1-3]

MATERIALS & METHODS

Determination of ATC

The ATC of the system duly represents the further participation ability in power market for trading among the group of seller and buyers. It also indicates the future probable planning for the transmission network to keep security and reliability as pronounced. By this determination congestion in the power network can be reduced. The lines are loaded up to their maximum thermal limit without any electrical accidents. The power flow scheduling is to be done by keeping the records of ATC of lines under different transaction between the seller and the buyer in wholesale power market.

There are different methods reported in the literature to find ATC, namely, continuation power flow (CPF), DC Power transfer distribution factor and AC-Power transfer distribution factor (AC-PTDF). Among all these methods AC-PTDF will provides the accurate value of ATC in the lines. [9, 10]

Determination of shortest path

The graph theory techniques are used in determination of shortest path in the power network. The proposed Dijkstra's Algorithm is the direct solution technique to get the solution based on searching the shortest path between power producers and consumers among all the possible paths with graphical representation. From this the line losses are reduces considerably by providing the path of low impedance so that power wheeling is reduces. If DSM is implemented using this concept in the power system planning the lines losses will be minimized [7, 8].

PTDF Calculation

PTDFs determine the linear impact of a transfer of power on the elements of the power system. These values provide a liberalized approximation of how the flow on the transmission lines and interfaces change in response to transactions between the seller and buyer. The power transfer limit one the lines depends on the PTDF value, as PTDF is positive, so look for the element overload in the positive direction. If PTDF value is very small which means that the transfer has a very small impact on the limiting element? If PTDF is negative, so look for the element overload in the negative direction. The transfer limit is inversely proportional to the PTDF and ATC is the minimum of transfer constraint. Hence line having highest PTDF is the limiting factor for particular transaction but every time this is not true because limiting factor also depend on system topology, thermal constraint and on percentage loading of the line. [9,10]

$$TM = \frac{\text{Limit M} - \text{MW flow}}{\text{PTDF}} \quad ; PTDF > 0 \quad \text{-------} \ (1)$$

$$PTDF = 0 \quad \text{-------} \ (2)$$

$$TM = \frac{-\text{Limit M} - \text{MW flow}}{\text{PTDF}} \quad ; PTDF < 0 \ \text{---------} \ (3)$$

The simulation using power world simulator is carried out on IEEE-9 bus system. The line data, generator and load details are shown in Table.1& 2.

PTDF values of the transmission system indirectly represent the current load which is being carried by the element and ultimately help to find out the Available Transfer Capacity (ATC). The same is very useful for the power trading between the seller and buyer corporations as well as for the open market transactions. A simulated sample system as shown in Fig.1 is taken for the case study. The details of the system are shown in Table 3.before congestion load flow in the system. The simulation change in the load and outage of lines was done and PTDF values are displayed on the single line diagram (SLD). The sample system posses good PTDFs and have good margin to load further. This opportunity of loading further emphasizes the calculation of available transfer capacity (ATC) of the system [9, 10].

RESULTS & DISCUSSION

The simulation with line outage between buses 2-6 creates congestion in the system. After diverting the power through other line new PTDF values are displayed on the single line diagram (SLD). The sample system posses good PTDFs and have good margin to load further. This opportunity of loading further emphasizes the calculation of available transfer capacity (ATC) of the system.

Table.1 Line data & maximum capacity of lines

No. of lines	Line between buses	Impedance of line	Maximum capacity of line
1	1-2	0.10+j0.20	100 MVA
2	1-4	0.5+j0.2	100 MVA
3	2-3	0.05+j0.25	100 MVA
4	2-5	0.05+j0.10	100 MVA
5	2-6	0.07+j0.20	100 MVA
6	3-6	0.02+j0.10	100 MVA
7	4-5	0.20+j0.40	100 MVA
8	4-7	0.25+j0.29	100 MVA
9	5-6	0.10+j0.30	100 MVA
10	5-8	0.32+j0.42	100 MVA
11	6-9	0.35+j0.42	100 MVA
12	7-8	0.18+j0.24	100 MVA
13	7-9	0.28+j0.32	100 MVA

Table.2. Generator and load details on the buses

Buses	Generator		Load	
	MW	MVAR	MW	MVAR
1 (slack bus)	100	0		
2	--	--	50	20
3	60	0	---	---
4	--	---	100	50
5	--	--	75	70
6	--	--	80	50
7	--	--		
8	100	20		
9	100	20		

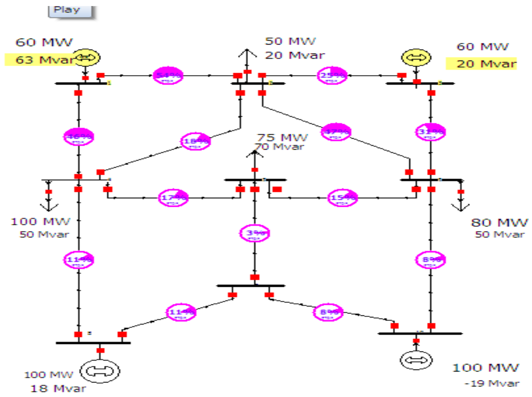
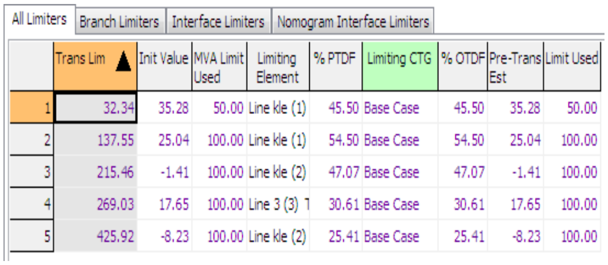


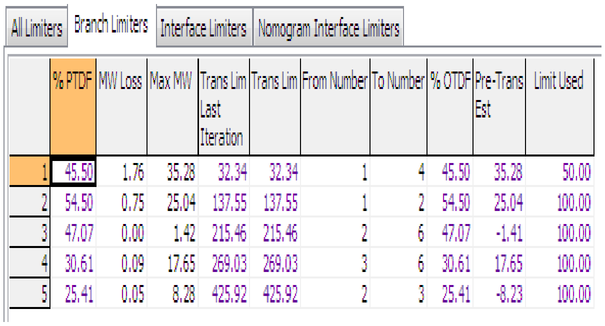
Fig1. Simulated single line diagram of system before congestion

Table.3 Transmission limit and PTDF values before congestion



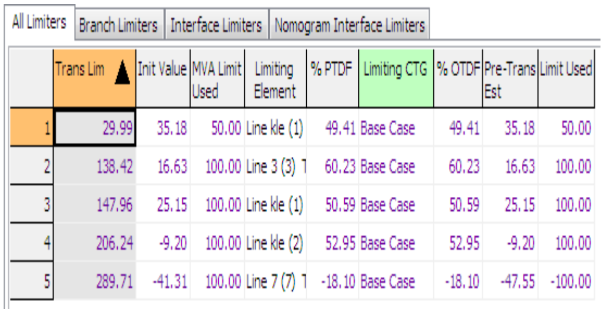
	Trans Lim ▲	Init Value	MVA Limit Used	Limiting Element	% PTDF	Limiting CTG	% OTDF	Pre-Trans Est	Limit Used
1	32.34	35.28	50.00	Line kle (1)	45.50	Base Case	45.50	35.28	50.00
2	137.55	25.04	100.00	Line kle (1)	54.50	Base Case	54.50	25.04	100.00
3	215.46	-1.41	100.00	Line kle (2)	47.07	Base Case	47.07	-1.41	100.00
4	269.03	17.65	100.00	Line 3 (3) T	30.61	Base Case	30.61	17.65	100.00
5	425.92	-8.23	100.00	Line kle (2)	25.41	Base Case	25.41	-8.23	100.00

Table.4. Maximum power flow and power losses in the lines before congestion



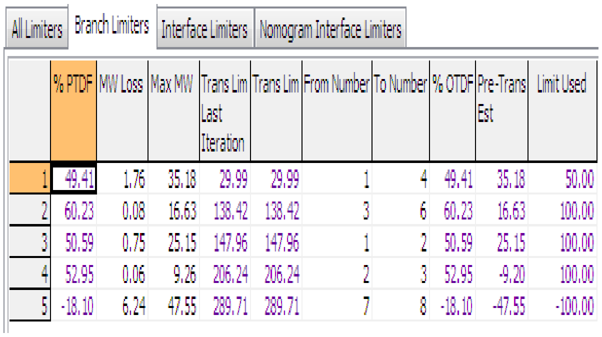
	% PTDF	MW Loss	Max MW	Trans Lim Last Iteration	Trans Lim	From Number	To Number	% OTDF	Pre-Trans Est	Limit Used
1	45.50	1.76	35.28	32.34	32.34	1	4	45.50	35.28	50.00
2	54.50	0.75	25.04	137.55	137.55	1	2	54.50	25.04	100.00
3	47.07	0.00	1.42	215.46	215.46	2	6	47.07	-1.41	100.00
4	30.61	0.09	17.65	269.03	269.03	3	6	30.61	17.65	100.00
5	25.41	0.05	8.28	425.92	425.92	2	3	25.41	-8.23	100.00

Table.5 Transmission limit and PTDF values after congestion



	Trans Lim ▲	Init Value	MVA Limit Used	Limiting Element	% PTDF	Limiting CTG	% OTDF	Pre-Trans Est	Limit Used
1	29.99	35.18	50.00	Line kle (1)	49.41	Base Case	49.41	35.18	50.00
2	138.42	16.63	100.00	Line 3 (3) T	60.23	Base Case	60.23	16.63	100.00
3	147.96	25.15	100.00	Line kle (1)	50.59	Base Case	50.59	25.15	100.00
4	206.24	-9.20	100.00	Line kle (2)	52.95	Base Case	52.95	-9.20	100.00
5	289.71	-41.31	100.00	Line 7 (7) T	-18.10	Base Case	-18.10	-47.55	-100.00

Table.6. Maximum power flow and power losses in the lines after congestion



	% PTDF	MW Loss	Max MW	Trans Lim Last Iteration	Trans Lim	From Number	To Number	% OTDF	Pre-Trans Est	Limit Used
1	49.41	1.76	35.18	29.99	29.99	1	4	49.41	35.18	50.00
2	60.23	0.08	16.63	138.42	138.42	3	6	60.23	16.63	100.00
3	50.59	0.75	25.15	147.96	147.96	1	2	50.59	25.15	100.00
4	52.95	0.06	9.26	206.24	206.24	2	3	52.95	-9.20	100.00
5	-18.10	6.24	47.55	289.71	289.71	7	8	-18.10	-47.55	-100.00

Table 7. Shows the % PTDF value before congestion and after congestion. The ATC value is proportional to PTDF values. As seen in the simulation diagram still the lines have available transfer capacity. The system is under secure condition when transaction takes place between the bus- and 6. The lines can be loaded for the further transaction between seller and buyer.

Table.7. Comparison table of PTDF values before and after congestion

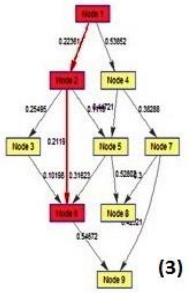
Buses	Before congestion load flow % PTDF	After congestion load flow %PTDF
1-2	54%	51%
1-4	46%	49%
2-3	25%	53%
2-4	18%	2%
2-6	47%	**OUT**
3-6	31%	60%
4-5	17%	29%
4-7	11%	18%
5-6	15%	26%
5-8	3%	5%
6-9	8%	13%
7-8	11%	18%
7-9	8%	13%

Determination of shortest path between the seller and buyer

Fig 3 shows the shortest path between bus-1 and 6 before the line outage condition. It follows that path 1-2-6. After the line outage congestion the power flow path changed to next shortest path 1-2-3-6 which is minimum loss path compared to other paths between bus 1&6 as shown in Fig.4.

CONCLUSION

The proposed method of ATC calculation and determination of shortest path power flow in concepts helps in Congestion Management and Demand Side Repose in Wholesale Power Market. The simulation studies are carried out on IEEE- 9 bus system. When demand increase and line outage condition there is congestion in the power network. In wholesale power market this is always happens because of many IPPs and many power flow paths. For available transfer capacity of interconnected systems results are shown on different line outage conditions with different PTDF/OTDF values. To identifying shortest path graph theory Dijkstra's algorithm is implemented on the power network. The simulation is carryout using power world simulator and MATLAB and found satisfactory results.



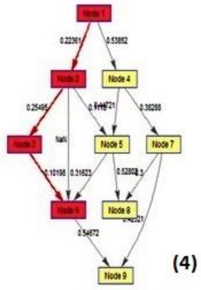


Fig.3.Shortest path between bus 1 & 6 before congestion

Fig.4. shortest path between 1 & 6 after congestion (line out between 2&6)

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